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REMOTE SENSING OF OCEAN CURRENTS

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16. Abstract

Monthly field experiments in support of the NOAA investigation of ocean color boundary determination using ERTS data have been conducted since June 1972. The color boundary between the Loop Current and coastal water has been detected by airborne cameras with ERTS type band pass filters, at altitudes of 7300 meters. Ship and aircraft data hint that the boundary may be enhanced due to increased plytoplankton populations caused by convergence of the surface waters; the term "edge effect" is coined to describe this phenomenon.

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PREFACE

The objective of this investigation is to locate ocean current boundaries by sensing the color change associated with the cyclonic edge of the zone of maximum horizontal velocity shear. The test site is the eastern Gulf of Mexico where the strongly baroclinic flow from the Yucatan Straits forms into the Loop Current. The research is using ERTS' data in the investigation of ocean color sensing.

A time series of the location of the Loop Current was begun in August 1972. For every other transit of ERTS (i.e. 36 days) the current is located by ship. These data are being used to provide surface measurements in support of the spacecraft observations and to obtain the first time history of the circulation in the eastern Gulf of Mexico. A phenomenon coined the "edge effect" has been discovered which enhances the detection of oceanic color boundaries.

Further time histories of the variables which allow the use of ocean color as a current detection phenomenon are being made. These research cruises should be continued for at least one year in order to understand the seasonal variability associated with the circulation and detection of the circulation's surface indicators.

INTRODUCTION

This interim report covers the first six months of the ocean current detection project using ERTS data. Five field experiments have been conducted in support of the work, three of which are part of a continuing time history of the Loop Current. Several ERTS images appear to show the current boundary; the CCT's for these chips have been ordered for further processing.

FIELD DATA COLLECTION

Ship-aircraft experiments were performed in June and July. The first experiment had the NASA C-130 overfly the boundary of the Loop Current off Dry Tortugas. The C-130 obtained ERTS simulation photographs and imagery at seven altitudes while the research vessel obtained concurrent surface measurements of chlorophyll-a, volume scattering function, temperature, salinity, and spectral reflectance. In July a similar experiment was performed using the NASA 990; this was a cooperative project with Warren Hovis of GSFC to obtain spectral information across the oceanic front.

Ship-satellite experiments were performed in August, September and October. A time-series of the Loop Current is being obtained by occupying the suborbital track of ERTS that passes into the Yucatan Straits every 36 days. The research vessel is on the suborbital track on the day of satellite transit collecting continuous chlorophyll-a, volume scattering, and radiometric temperature (in conjunction with the NOAA-2 IR sensors); hourly (15 km interval) expendable bathythermograph, surface bucket temperature and salinity samples are being obtained. During daylight, spectra of upwelling and downwelling radiance (400-800 nm) are being measured with a $\frac{1}{4}$ meter Ebert scanning spectroradiometer. Upon reaching the Yucatan Straits a temperature/salinity/depth (STD) transect of nine stations is being made in order to determine the geostrophic current and transport fields. After the STD transect, the surface boundary of the Loop Current is being tracked using the same measurements outlined for the subsatellite track. A second STD transect of the Florida Straits from Key West to Havana is made in order to determine the discharge from the basin.

AIRCRAFT EXPERIMENT

The boundary between the Loop Current and the coastal waters near Dry Tortugas was photographed at several altitudes up to 7300 meters. At all altitudes the boundary was visible through a 47B filter and a 57 filter but not with the 25A or the 89B. This is a reasonable result that implies the ocean color boundary would be detectable in MSS 4 but not in the longer wavelength channels MSS 5, 6, or 7.

The edge of the color boundary frequently has a narrow band of algae floating on the surface. These algae were photographed during part of the experiment and were seen to have high reflectance in the red (25A) and near IR (89B) but much lower in the blue and green. This implies that MSS 5 and 6 may be useful if the spatial scale of the algae is large enough to be detected.

In addition, since the edge of the color boundary is an active convergence, the concentration of plytoplankton tends to reach a maximum there. This causes the chlorophyll to peak to a maximum very near the edge and enhance the detection of color difference. It is proposed to call the phenomenon discussed in these paragraphs the "edge effect" because they tend to enhance the boundary sharpness and contribute to the ease of its location by remote sensing.

SHIP EXPERIMENT

Location of the Loop Current by ship has been proceeding routinely for three months. The current has been south of the latitude of Dry Tortugas and there are indications of a large semi-permanent detached eddy north of the main current. The main body of the Loop Current has been observed to move more than 25 kilometers per day but it appears to be oscillatory rather than translational. Mass flux measurements have been taken and computations are being programmed; results are not available at this writing.

Spectral signatures in plankton blooms have been obtained and have been compared to spectra from coastal and sterile waters. These measurements show several major inconsistencies with data reported in the literature. Theoretical calculations agree qualitively with the recent measurements made on these cruises. This issue is being further pursued with additional calculations and measurements.

Continuous flow measurements of surface fluorescence and surface temperature show significant high (spatial) frequency fluctuations. This supports many older Nimbus analyses of the ocean's surface. A high correlation inverse relation between surface temperature and fluorescence has been observed during these cruises. Such patchiness will contribute to high variability in ocean color.

ERTS DATA

The first ERTS data tape has been read and an along-scan profile of the four channels in an area of oceanographic interest has been machine plotted. There appears to be several-fold more useful information is the digital data than in the 70 mm film chips. A first evaluation suggests high (spatial) frequency variability; this is being investigated by transforming the data into conventional time-series format for analysis with the FESTSA series of subroutines.

Several chips have been selected for digital analysis. These scenes appear to show the current flow in the Yucatan Straits and the Florida Straits. No indications of the current have been detected in the deep sea; these areas will be investigated after regions of higher signal to noise ratio have been studied.

Certain features have been detected in the scenes which are contrary to the spectral measurements taken by the ships. That is, the current appears in MSS 5 as a brighter region. This must be interpreted that the blue water of the current reflects more energy than the green water of the coast. The only way for this to be possible is for higher sea states or more isotropic scatters to characterize the current. Higher sea states are ordinarily observed in the current and if the interpretation is indeed oceanic and not atmospheric, then sea state is the important indicator of the current, and not color. This proposition is being further investigated.

PROGRAM FOR NEXT REPORTING INTERVAL

Cruises every 36 days will continue as before. In addition, biological samples are being drawn for analysis by FSU.

These analyses will supplement the physical observations and contribute toknowledge of the variations in the plankton and how they may influence the ratio of scattering to absorbing materials. Emphasis with CCT's will be placed on adopting pattern recognition algorithms in selected cases. Analysis of the aircraft MSS data (just received) will commence cooperatively with MSC, Houston.

CONCLUSIONS

The New York Bight chip of 16 August, clearly demonstrated that the ERTS returns information of oceanographic importance. Other regions, such as the Yucatan and Florida Straits chips mentioned in this report, show promise and require further study. The edge effect discovered in this work enhances the possibility of detecting current boundaries; its impact on the remote sensing of ocean currents in the absence of thermal gradients will be exploited in the next interim period.

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